Research Article

Measuring balance confidence after spinal cord injury: the reliability and validity of the Activities-specific Balance Confidence Scale

Garima Shah[1], Alison R. Oates[2], Tarun Arora[3], Joel L. Lanovaz[2], Kristin E. Musselman[1,3,4]

[1]SCI Mobility Lab, Toronto Rehabilitation Institute-University Health Network, Toronto, ON, [2]College of Kinesiology, University of Saskatchewan, Saskatoon, SK, [3]Faculty of Medicine, University of Saskatchewan, Saskatoon, SK, [4]Dept. of Physical Therapy, Faculty of Medicine, University of Toronto, Toronto, ON.

Context/Objective: The study objectives were to evaluate the test-retest reliability, convergent validity, and discriminative validity of the Activities-specific Balance Confidence (ABC) scale in individuals with incomplete spinal cord injury (iSCI).

Design: Prospective, cross-sectional study.

Setting: Laboratory.

Participants: Twenty-six community-dwelling individuals with chronic iSCI (20 males, 59.7 $\pm$ 18.9 years old) and 26 age- and sex-matched able-bodied (AB) individuals participated.

Interventions: None.

Outcome Measures: Measures of balance and gait were collected over two days. Clinical measures included the ABC scale, Mini-Balance Evaluation System's Test, 10-meter Walk Test, SCI Functional Ambulation Profile, manual muscle testing of lower extremity muscles, and measures of lower extremity proprioception and cutaneous pressure sensitivity. Biomechanical measures included the velocity and sway area of centre of pressure (COP) movement during quiet standing.

Results: The ABC scale demonstrated high test-retest reliability (intraclass correlation coefficient = 0.93) among participants with iSCI. The minimal detectable change was 14.87%. ABC scale scores correlated with performance on all clinical measures (ρ=0.60-0.80, $P<0.01$), with the exception of proprioception and cutaneous pressure sensitivity ($P=0.20–0.70$), demonstrating convergent validity. ABC scale scores also correlated with overall COP velocity (ρ=-0.69, $P<0.001$) and COP velocity in the anterior-posterior direction (ρ=-0.71, $P<0.001$). Participants with iSCI scored significantly lower on the ABC scale than the AB participants ($P<0.001$), and the area under the receiver operating characteristic curve was 0.95, demonstrating discriminative validity.

Conclusion: The ABC scale is a reliable and valid measure of balance confidence in community-dwelling, ambulatory individuals with chronic iSCI.

Keywords: Spinal cord injuries, Balance confidence, Validity, Reliability

Introduction

Impaired balance is one of the many consequences of spinal cord injury (SCI). As a result, the incidence of falls is high, especially for those with incomplete SCI (iSCI); 75% of these individuals fall in a given year.[1] Balance impairments and a history of falls may put individuals with iSCI at risk of developing a fear of falling.[2]

The impact of a fear of falling has not yet been described for people with SCI; however, in other populations a fear of falling is associated with decreased quality of life, depression, anxiety, reduced participation in mobility and activities of daily living, and physical and mental decline.[3–8]

In older adults, a fear of falling often manifests as a low score on a measure of balance self-efficacy or confidence.[9] Balance confidence or self-efficacy is "a person's level of confidence in the ability to maintain balance

Address correspondence to: Kristin Musselman PT, PhD SCI Mobility Lab, Lyndhurst Centre-TRI, 520 Sutherland Drive, Toronto ON, M4G 3V9, Canada 416-597-3422 x6190 Kristin.Musselman@uhn.ca

while performing specific daily activities".[10] One scale commonly used to gauge balance self-efficacy is the Falls Efficacy Scale (FES), which assesses the degree of perceived efficacy at avoiding falls during ten relatively nonhazardous daily living activities, such as getting in and out of bed and getting dressed/undressed.[11] Among individuals with SCI, lower FES scores, suggesting greater self-efficacy, were associated with greater balance performance on the Berg Balance Scale[12] and reduced postural sway during standing[13].

Another similar scale is the Activities-specific Balance Confidence (ABC) scale. Individuals rate how confident they are that they can maintain their balance while performing 16 standing and walking tasks, such as walking around the house, and sweeping the floor.[14] Although originally devised for use in older adults, the ABC scale has been used with the SCI population.[15–17] Compared with the FES, the ABC scale includes more challenging mobility tasks, such as negotiating escalators, which may make it better suited for ambulatory individuals. The scale's psychometric properties have not been evaluated among individuals with iSCI; however, it is a valid and reliable scale for healthy older adults,[14] individuals with lower limb amputations[18] and those with multiple sclerosis[19, 20] and stroke.[2] The objectives of the present study were to: (1) Assess the test-retest reliability of the ABC scale in individuals with chronic iSCI and establish its minimal detectable change (MDC) in this population. (2) Assess the convergent validity of the ABC scale in the same individuals with iSCI by correlating scores on the ABC scale with measures of balance, walking, strength, and sensation. (3) Assess the discriminative validity of the ABC scale (i.e. its ability to distinguish between individuals with iSCI and age- and sex-matched able-bodied (AB) adults).[21] We hypothesized that the ABC scale would show high test-retest reliability, and convergent and discriminative validity, among the chronic iSCI population.

Methods

This prospective, cross-sectional study involved two testing sessions on consecutive days. At these sessions, clinical and biomechanical data related to balance and walking were collected, including the ABC scale. Participants were asked to complete a second ABC scale two weeks after the testing sessions either over the phone with a researcher or independently on paper, which was subsequently mailed to our research team. Approval for this study was granted by the University of Saskatchewan Research Ethics Board.

Participants

Participants with iSCI were recruited through the two major health regions in Saskatchewan and private physical therapy clinics. All participants were adults (i.e. ≥ 18 years of age) who sustained a traumatic or non-progressive, non-traumatic SCI that was motor incomplete (i.e. American Spinal Injury Association Impairment Scale (AIS) grade C or D) at least one year prior (i.e. chronic injury). Addition inclusion criteria included presently living in the community and being able to walk for 14 m (walking devices, braces and physical assistance permitted). Participants were excluded if they had a vestibular impairment, or any other disease, injury, or condition that affected their walking or balance. A sample size calculation was performed in Microsoft Excel based on the expected test-retest reliability of the ABC scale (i.e. intraclass correlation coefficient (ICC)). Given an expected ICC of 0.90,[18, 22] two observations per participant (i.e. two administrations of the scale) and 95% confidence, 24 participants with SCI were required.[23]

AB participants were recruited through University of Saskatchewan listservs. Those who were an age (+/- 3 years) and sex match to a participant with SCI were invited to participate. AB volunteers were excluded if they had any disease, injury, or condition that affected walking or balance.

Clinical Measures

At the first testing session participants completed clinical measures of balance, walking, strength, and sensory function, as these abilities could impact perceived balance confidence. A researcher with a background in physical therapy (TA) administered the measures. Rest breaks were taken as needed, and the order of the measures varied for each participant depending on the availability of lab space. While participants with iSCI completed all measures listed below, AB participants completed the ABC scale.

1) *The ABC Scale* rates perceived confidence in performing 16 different standing and walking activities.[14] The majority of these tasks involved functional variations of walking such as climbing up and down the stairs or walking on a ramp. The respondent rates his/her confidence in performing each activity without losing balance by selecting a value between 0% (no confidence) to 100% (completely confident).

2) *The Mini-Balance Evaluation System's Test (mini-BESTest)* is a 14-item test scored on a 3-level ordinal scale.[24] The Mini-BESTest assesses four balance control systems; anticipatory postural adjustments, reactive postural control, sensory orientation, and dynamic gait. Sub-scores were calculated for each system as well as a total score (/28). The Mini-

BESTest has good reliability and validity in individuals with stroke[25] and Parkinson's disease.[26] In individuals with chronic iSCI, the Mini-BESTest is associated with measures of postural steadiness.[27]

3) *The isometric strength of lower extremity muscle groups* (hip extensors, hip flexors, hip abductors, hip adductors, knee extensors, knee flexors, ankle plantarflexors, ankle dorsiflexors) were tested bilaterally using manual muscle testing.[28] Testing positions were standardized across participants. A total score (/80) was calculated by summing the individual muscle group scores for both legs (eight muscles/leg x maximum score of five/ muscle).

4) *Proprioception* of the ankle and distal phalanx of the big toe were tested bilaterally.[29] Participants were instructed to close their eyes and indicate whether the researcher moved their joint in an up or down direction. Six trials were performed per joint and the number of correct responses across joints was recorded and expressed over a total score of 24 (six trials x two joints x two legs).

5) *Cutaneous Pressure of the Big Toe* was tested bilaterally using monofilaments (Baseline® Tactile™ Monofilaments). With their eyes closed, participants indicated when they felt a monofilament touch the plantar surface of their big toe. Five sizes of monofilaments with varying diameters and tensile strengths were used, ranging from 6.65–2.83 grams of force when applied to the skin. The monofilaments were presented in order of greatest to smallest size, with each monofilament being presented six times. The total number of correct responses was recorded and expressed over a total score of 60 (six trials x five monofilaments x two toes).

6) *The 10-meter Walk Test (10MWT)* is a measure of self-selected and fast walking speeds over a short distance. Participants walked in a straight line for 14 m (middle 10 m timed) with assistive devices as needed. The 10MWT has demonstrated excellent reliability and validity in SCI.[30]

7) *The Spinal Cord Injury Functional Ambulation Profile (SCI-FAP)* measures performance on seven functional walking tasks.[31] In this study, a shortened version of five SCI-FAP tasks was used: the Carpet, Up and Go, Stairs, Step, and Obstacle tasks.[31] A score for each task is derived from the time taken, and the amount of assistance required, to complete the task. Lower scores indicate greater speed and/or less assistance. The SCI-FAP is a valid, reliable, and responsive measure in individuals with chronic, incomplete SCI.[31, 32]

8) *The Walking Index for Spinal Cord Injury II (WISCI II)* is a 21-point ordinal scale that reflects the amount of physical assistance, walking devices, and bracing required to walk 10 m in individuals with SCI.[33] The self-selected WISCI II score, which describes how an individual walks in the community,[34]

was used to describe the walking status of participants with SCI.

9) *Falls and Fear of Falling* were queried. Participants were asked if they had fallen in the past year. They were also asked if they had a fear of falling, which was defined as "a lasting concern about falling causing them to avoid or curtail activities they felt they were capable of doing".[9] A yes or no response was recorded for both the presence of falls and a fear of falling.

Biomechanical Measures

At the second testing session center of pressure (COP) movement characteristics were assessed. Participants were asked to stand with their eyes open, shoes on, and with their feet at a self-selected comfortable position for 60 seconds on a force platform mounted flush with the floor (18.25×20 inches, AMTI OR6-7, Advanced Mechanical Technology, Inc., Watertown, MA). Force platform data were sampled at 2000Hz and filtered at 10 Hz with a 4th order low-pass Butterworth digital filter to determine COP movement characteristics. Kinematic data were captured using a 3D motion capture system (Vicon Nexus, Vicon Motion Systems, Centennial, CO) and sampled at 100 Hz. The base of support (BOS) dimensions were calculated from kinematic markers at three locations on each foot (heels, distal end of first toe, and the most lateral part of the foot at the base of the fifth metatarsal). Custom MATLAB (R2006b for PC, MathWorks, Natick, MA) routines were used to obtain COP and BOS data. COP data were analyzed to determine the amount, velocity, and variability of sway during standing. All of the COP measures calculated are reliable and valid for individuals with iSCI.[35]

Data Analysis

The amount of sway was measured by calculating the area of an ellipse, centered at the mean, which encompasses 90% of the COP samples for that trial (Area90). To further distinguish how far the COP moved in each horizontal plane, the length of the radius of the ellipse in the medio-lateral (ML) and anterior-posterior (AP) were calculated (Area90_MLr and Area90_APr). Similarly, velocity of the COP movement was calculated in the ML and AP directions (ML_vel and AP_vel). Total velocity was calculated by taking the resultant distance between two points divided by the time between those two points. The final average value represents the overall COP velocity (Path_Vel). Root mean square (RMS) was calculated in both horizontal planes to reflect variability of COP movement (ML_RMS and AP_RMS). The RMS and Area90

values were normalized to the size of the individual's BOS: AP values were normalized to the length of the BOS, ML values were normalized to the width of the BOS, and the Area90 values were normalized to the area of the BOS. All normalized values are indicated with an "n" (e.g. ML_RMSn).

Group scores on the clinical and biomechanical measures, and demographic variables, are reported as mean $\pm$ 1 standard deviation and range, as appropriate. All statistical tests were completed in IBM SPSS 24. Alpha was set to 0.01 due to the large number of tests performed. The Shapiro-Wilk test was used to test the assumption of normality. To evaluate test-retest reliability, a one-way random effects ICC for absolute agreement was used. The MDC at a 95% confidence interval (MDC_{95}) was calculated as follows: MDC_{95} = SEM$\times 1.96 \times \sqrt{2}$.[36] The SEM, or standard error of measurement, was calculated as follows: SEM = s_x $\sqrt{1-r_x}$, where s_x is the baseline standard deviation of ABC scale scores and r_x is the test-retest reliability.

To evaluate convergent validity scores on the ABC scale, collected at the first testing session, were correlated with the scores on the clinical measures (i.e. MiniBESTest, lower extremity strength, cutaneous pressure, proprioception, 10MWT, SCI-FAP task scores) and biomechanical measures (ML_vel, AP_vel, ML_RMSn, AP_RMSn, Path_vel, Area90n, Area90_APrn, Area90_MLrn). The Pearson correlation coefficient (r) was used for interval-level measures (e.g. 10MWT), and Spearman's rank-order correlation coefficient (ρ) was used for ordinal-level measures (e.g. miniBESTest) or variables that violated the assumption of normality. The magnitude of the correlation coefficient was interpreted as follows: < 0.25 = "little or no relationship", 0.25–0.50 = "fair degree of relationship", 0.50–0.75 = "moderate to good", and > 0.75 = "good to excellent".[37]

To evaluate discriminative validity, ABC scores were first compared between participants with SCI (i.e. first ABC scale administration) and AB participants using a two-tailed matched-pair *t* test or Wilcoxon signed-rank test, as appropriate. A receiver operating characteristic (ROC) curve analysis was completed to evaluate the ability of the ABC scale to discriminate the two groups. An area under the curve (AUC) of 1.0 indicated perfect differentiation, while an AUC of 0.50 indicated differentiation no better than chance.

Results

Twenty-six individuals with iSCI participated (20 males, 59.7 $\pm$ 18.9 years old, 5 AIS C, 21 AIS D) (see Table 1). Self-selected WISCI II scores ranged from 9 (walks with a walker, braces and no physical assistance) to 20 (walks without a device, braces or physical assistance). Twenty-six age- and sex-matched able-bodied individuals participated (20 males, 58.9 $\pm$ 18.1 years old).

Nineteen participants with SCI (73%) reported at least one fall in the past year and 13 participants (50%) reported a fear of falling. ABC scale scores ranged from 21.3% to 95.3% (first administration). Scores on the clinical measures of balance, walking, strength and sensory function are reported in Table 2.

Biomechanical data were collected from 21 participants with SCI (see Table 3). There was an equipment malfunction during Participant 11's experiment that resulted in no force plate data being collected. Four of the lower-functioning participants (Participants 2, 3, 4 and 20) were unable to stand independently on the forces plates for > 60s, which was required for collection of the biomechanical data. A wide range of values were observed for the velocity and sway area of the COP.

Test-retest reliability

All but one participant completed the ABC Scale a second time. Two participants completed the second ABC scale 5.3 and 6.0 weeks later, and were excluded from the analysis of test-retest reliability. Hence, test-retest reliability was calculated with data from 23 participants. The mean length of time between administrations of the ABC scale for the group was 2.4 $\pm$ 0.7 weeks. The mean group scores on the first and second administrations of the ABC scale were 67.5. $\pm$ 20.3% (range 21.3–95.3%) and 64.1 $\pm$ 19.4% (18.8–95.3%), respectively. The test-retest reliability of the ABC scale was high (ICC = 0.93, 95% confidence interval (CI) = 0.85–0.97).

Only one participant showed notably different scores on the two administrations of the ABC scale, which were spaced 2.0 weeks apart (see Figure 1). This participant scored 73.1% the first time, followed by 38.1% the second time. This individual fell once during the interval between ABC scale administrations; however, he also reported experiencing 3–4 falls in the year prior to the study. Thus, falling would not have been a new experience for him.

The SEM of the ABC scale was calculated to be 5.37% (using s_x = 20.28% and r_x = 0.93). The MDC_{95} was calculated to be 14.87%.

Convergent validity

Scores on the ABC scale showed significant (P < 0.01), moderate to excellent correlations with scores on clinical measures of balance, gait, and lower extremity strength, but not lower extremity proprioception and cutaneous pressure (see right-most columns, Table 2). The

Table 1. Characteristics of Participants with SCI

Participant	Age (years)	Sex (M/F)	Mass (kg)/ Height (m)	Injury Level*	Years Post-SCI	AIS Level	Self-selected WISCI II	Walking device/ brace used
1	51.4	M	123/1.92	L1	5.8	D	20	None
2	24.0	M	78/1.80	C2	7.0	C	9	4WW, 1AFO
3	70.5	F	90.6/1.62	C7	2.8	C	9	4WW, 1AFO
4	52.4	M	64/1.74	C6	3.7	C	13	2WW
5	76.0	M	81/1.68	C3	10.0	D	20	None
6	40.6	M	72/1.80	T12	7.8	D	20	None
7	72.9	M	78/1.71	L4	7.0	D	20	None
8	47.5	M	81/1.67	C5	4.9	D	20	None
9	62.6	M	84/1.78	C5	9.1	D	9	4WW, 1AFO
10	29.8	M	64/1.75	L1	7.5	D	18	1 AFO
11	54.7	M	79/1.72	C4	3.0	D	20	None
12	46.3	F	69/1.61	C4	2.5	D	20	None
13	86.4	F	61/1.56	C4	3.3	D	20	None
14	65.7	M	71/1.81	C4	18.1	D	20	None
15	74.2	M	87/1.78	T11	3.0	D	20	None
16	45.2	M	92/1.80	T12	2.8	C	12	FC, 2 AFO
17	84.9	M	79/1.60	C3	4.2	D	13	4WW
18	70.3	M	131/1.87	C6	14.6	D	15	1 cane, 1 AFO
19	72.4	M	86/1.76	T4	47.9	D	19	1 cane
20	52.3	M	83/1.71	T11	2.9	C	9	2WW
21	95.1	F	60/1.50	C1	4.7	D	13	4WW
22	32.0	M	79/1.89	L4	7.9	D	20	None
23	64.8	M	116/1.73	T10	2.2	D	20	None
24	67.9	F	78/1.62	C5	7.4	D	20	None
25	48.7	M	97/1.89	C4	2.0	D	20	None
26	41.0	F	83/1.71	T8	2.1	D	20	None

*indicates the neurological level of the SCI; 4WW=4 wheeled-walker; AFO=ankle-foot orthosis; 2WW=2 wheeled-walker; FC=forearm crutches.

correlation between ABC scale scores and total MiniBESTest scores was good to excellent ($\rho=0.76$, $P<0.001$) (see Figure 2), while the sub-scores reflecting different balance control systems showed moderate to good correlations ($\rho=0.60–0.69$, $P\leq0.001$). The fast 10mWT showed the greatest correlation with ABC scale scores ($r=0.80$, $P<0.001$) (see Figure 2). All SCI-FAP task scores showed moderate to excellent correlations with ABC scale scores ($\rho=-0.67$ to -0.76, $P\leq0.001$). The Step task showed the greatest correlation among the SCI-FAP tasks ($\rho=-0.76$, $P<0.001$).

Two biomechanical measures showed a significant correlation with the ABC scale: Path_vel ($\rho=-0.69$, $P<0.001$) and AP_vel ($\rho=-0.71$, $P<0.001$) (see right-most columns in Table 3). Hence, as ABC scale score increased, the velocity of the COP decreased, especially in the AP direction.

Discriminative validity

On average, participants with iSCI scored significantly lower on the ABC scale than their age- and sex-matched AB peers ($67.5\pm20.3\%$ (range 21.3–95.3%) versus $94.5\pm7.3\%$ (range 65.6–100%), $Z=-4.381$, $P<0.001$). One AB participant aged 86.7 years scored 65.6% on the ABC scale; however, all other AB

participants scored 84.4% or greater. The ROC analysis showed an AUC of 0.95 (95% CI = 0.89–1.00).

Discussion

The results support the study hypotheses; the ABC Scale has high test-retest reliability, and convergent and discriminative validity, in a sample of community-dwelling, ambulatory individuals with chronic iSCI. Participants with iSCI reported very similar scores on two administrations of the ABC scale, demonstrating high test-retest reliability. Among the participants with iSCI, ABC scale scores showed moderate to excellent correlations with measures of balance ability (i.e. the mini-BESTest), walking speed (i.e. 10mWT), walking function (i.e. SCI-FAP) and lower limb strength, supporting convergent validity. The correlations were strongest between ABC scale scores and fast walking speed, perhaps reflecting the ABC scale's focus on ambulatory tasks. Finally, individuals with iSCI reported significantly lower scores on the ABC scale than their AB peers. This, combined with the results from the ROC analysis, suggest the ABC scale has discriminative validity.

The values calculated here for SEM (5.37%) and/or MDC$_{95}$ (14.87%) are comparable to the SEM and MDC values calculated for individuals with stroke

Table 2. Scores on Clinical Measures and Correlations with ABC Scale Scores

Clinical Measure		Mean ± SD (range)	Correlation with ABC Scale	
ABC Scale (%)	Administration 1	67.5 ± 20.3 (21.3–95.3)	Coefficient (r or ρ)	p-value
Mini-BESTest	Anticipatory (/6)	3.2 ± 1.6 (0–6)	ρ=0.69	<0.001*
	Reactive Postural Control (/6)	2.7 ± 2.4 (0–6)	ρ=0.60	0.001*
	Sensory Orientation (/6)	3.9 ± 2.0 (0–6)	ρ=0.66	<0.001*
	Dynamic Gait (/10)	5.9 ± 3.3 (0–10)	ρ=0.68	0.001*
	Total (/28)	15.7 ± 8.6 (2–27)	ρ=0.76	<0.001*
Lower extremity strength	Total (/80)	60.8 ± 11.0 (36–74)	ρ=0.60	0.001*
Sensory function	Proprioception (/24)	19.4 ± 4.8 (6–24)	ρ=0.26	0.199
	Cutaneous Pressure (/72)	31.0 ± 14.8 (0–52)	ρ=0.08	0.704
10-meter walk test (m/s)	Self-selected 10MWT	0.84 ± 0.42 (0.09–1.46)	r=0.76	<0.001*
	Fast 10MWT	1.16 ± 0.59 (0.10–2.07)	r=0.80	<0.001*
SCI-FAP^	Carpet	7.2 ± 12.6 (0.8–55.8)	ρ=-0.75	<0.001*
	Up and go	13.0 ± 25.2 (0.9–111.1)	ρ=-0.67	<0.001*
	Obstacles	11.7 ± 21.2 (0.9–79.6)	ρ=-0.69	<0.001*
	Stairs	10.3 ± 17.5 (0.8–82.9)	ρ=-0.72	<0.001*
	Step	26.3 ± 62.2 (0.6–300)	ρ=-0.76	<0.001*

^For the Spinal Cord Injury Functional Ambulation Profile (SCI-FAP), a lower score suggests higher function. Mean score of able-bodied adults on each SCI-FAP task is 1; thus a score <1 or >1 suggests the task was performed more quickly or slowly, respectively, than the average able-bodied adult.[31] *indicates statistically significant correlation (i.e. p<0.01).

Table 3. Scores on Biomechanical Measures and Correlations with ABC Scale Scores

Biomechanical Measures	Mean +/- SD (range)	Correlation with ABC Scale Coefficient (ρ)	p-value
Path_vel (mm/s)	23.0 ± 14.4 (8.7–74.8)	-0.69	<0.001*
ML_vel (mm/s)	11.7 ± 10.6 (2.5–53.0)	-0.51	0.019
AP_vel (mm/s)	17.1 ± 8.6 (7.9–41.8)	-0.71	<0.001*
ML_RMSn (mm)	1.6 ± 1.5 (0.2–7.6)	-0.32	0.154
AP_RMSn (mm)	2.9 ± 1.4 (1.3–7.5)	-0.01	0.953
Area90n (% of BOS total area)	0.6 ± 1.0 (0.1–5.0)	-0.210	0.361
Area90_APrn (% of BOS length)	4.8 ± 2.3 (2.1–12.9)	-0.03	0.887
Area90_MLrn (% of BOS width)	2.6 ± 2.6 (0.3–13.0)	-0.33	0.143

Path_vel = total velocity; vel = velocity; ML = medio-lateral; AP = anterior-posterior; RMS = root mean square; n = normalized to base of support (BOS) dimensions; Area90n = percent of the area of the ellipse normalized to the area of BOS; Area90_APrn = percent of the length of the AP semiaxis of the ellipse relative to the length of the BOS; Area90_MLrn = percent of the length of the ML semiaxis of the ellipse relative to the width of the BOS. *indicates statistically significant correlation (i.e. p<0.01).

were, on average, higher (i.e. mean 67.5±20.3%). The participants in this study were likely higher functioning as all were independent in ambulation. Hence, a potential limitation of this study is that the findings cannot be generalized to lower functioning individuals with SCI.

In the present study, ABC scale scores demonstrated moderate to excellent correlations with clinical measures of balance, walking function and lower extremity strength. Studies involving community-dwelling individuals with stroke have reported more modest correlations between the ABC scale and activity-level measures of balance and gait.[2, 38] This difference may be explained,

ABC Scale Scores

Figure 1: ABC scale scores at first (x-axis) and second (y-axis) administrations. Each triangle represents one participant. Black line indicates first ABC scale score = second ABC scale score.

(SEM=5.05–6.81%)[2, 38] and Parkinson's disease (SEM=4.01%, MDC=11.12–13%)[22, 39]. In two previous studies involving individuals with SCI,[15, 17] the change in ABC scales scores, not the raw scores, were reported. In one study[15] all four participants with iSCI scored <67%, which suggests a high fall risk for community-dwelling older adults.[40] In another case study, the ABC scale score of a participant with iSCI was reported both before (40.6%) and after (62.5%) locomotor training.[16] The ABC scale scores reported here
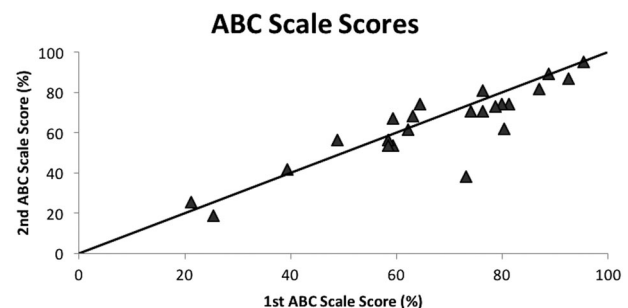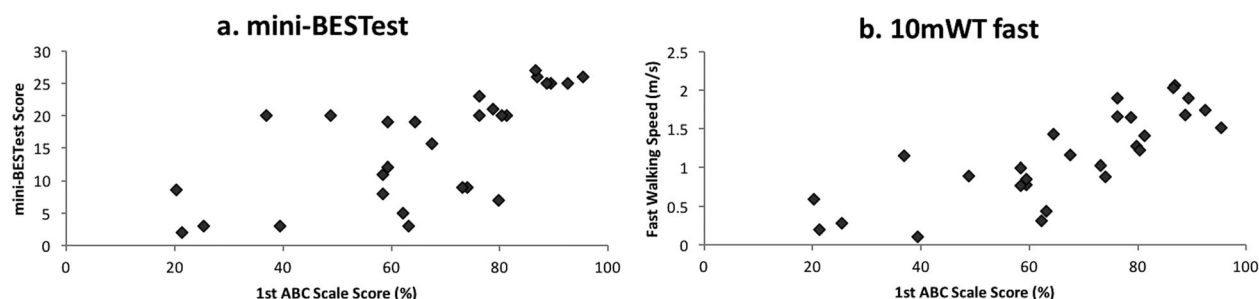
Figure 2: Scatterplots of ABC scale scores (first administration) with a. mini-BESTest total scores, and b. Fast walking speed as measured by the 10MWT. Each diamond represents one participant.

in part, by our participants with iSCI having greater walking function (e.g. mean self-selected gait speed in our participants with iSCI = 0.84 ± 0.42 m/s, compared with 0.4 ± 0.16 m/s[2] and 0.65 ± 0.35 m/s[38]). Stronger correlations between ABC scale scores and walking function (i.e. Dynamic Gait Index scores) were reported for individuals with mild or moderate unilateral peripheral vestibular dysfunction compared with those severely affected.[41] Thus, perceived balance confidence, as measured by the ABC scale, may more closely reflect actual balance performance in higher functioning individuals. These individuals may be more likely to perform the challenging tasks on the ABC scale, enabling them to be more accurate in their estimation of balance ability.

In this study, ABC scale scores did not correlate with lower limb proprioception or cutaneous pressure sensitivity, despite the importance of somatosensory feedback for maintaining balance.[42] Previous work, however, has shown that individuals with SCI rely on visual inputs for upright postural control, and likely down-weight the contribution of somatosensation.[27] Altogether, the correlations seem to suggest that in individuals with iSCI, ABC scale scores may be more closely related to performance on activities than the underlying sensorimotor impairments. This statement is further supported by our findings from the biomechanical measures of standing balance. The COP velocity and RMS values reported here match well with previous research investigating standing balance in individuals with iSCI.[27] However, only two COP measurements showed a significant correlation with ABC scale scores. The lack of correlation may be explained, in part, by how the COP measures were recorded; they were collected during static standing, whereas the ABC scale consists of mostly dynamic tasks.

In other populations the predictive value of the ABC scale has been studied. For example, scores below 67% and 69% indicate a high likelihood of falling in older adults and people with Parkinson's disease,

respectively.[40, 43] In individuals post-stroke, scores on the ABC scale can predict activity levels and community participation.[44,45] In individuals with multiple sclerosis, ABC scale scores can distinguish between those who use walking aids and those who do not, as well as between those who have experienced multiple falls and those who have not.[46] Future work should investigate how ABC scale scores can be interpreted for individuals with SCI.

Although the focus of the present study was balance confidence, data concerning falls and a fear of falling are also presented. Almost three quarters (73%) of the participants reported experiencing at least one fall in the previous year. This fall rate is consistent with previous literature.[1] Fifty percent of the participants reported a fear of falling. A fear of falling is linked to reduced postural control[13] and an increased fall risk[47] in individuals with SCI. In our study, ABC scale scores were similar between those participants who reported a fear of falling ($64.9 \pm 21.2\%$) and those who did not ($70.2 \pm 19.8\%$). Further investigation into the incidence and impact of a fear of falling in individuals with SCI, including the impact on balance confidence, is warranted.

Conclusion

The ABC scale is a valid and reliable measure of balance confidence in community-dwelling, ambulatory individuals with chronic iSCI. It is an appropriate measure for clinicians and researchers to use with this sub-group of SCI. Future work should focus on the responsiveness and interpretation of ABC scale scores in the SCI population.

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Disclaimer statements

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